

LESSON:

Chloramines and Elevated Blood Lead: Is the Effect Real?

Summary: Students evaluate data and identify potential factors important in determining an increase in blood lead levels of children of a municipality using chloramines as a disinfecting agent. They then provide an opinion about whether or not the data are strong enough to make decisions about using chloramines.

Lesson Type: Data Analysis—Students analyze data from published research.

EHP Article: "Chloramine Catch: Water Disinfectant Can Raise Lead Exposure"
EHP Student Edition, May 2007, p. A96
<http://www.ehponline.org/docs/2007/115-2/ss.html#chlo>

Objectives: By the end of this lesson, students should be able to

1. identify factors that put a child at risk of exposure to lead via drinking water;
2. interpret a line graph containing multiple variables; and
3. summarize the limitations of the scientific study referred to in the article.

Class Time: 1–1.5 hours

Grade Level: 11–12

Subjects Addressed: Biology, Chemistry, Environmental Science

► Prepping the Lesson (15 minutes)

INSTRUCTIONS:

1. Download the entire May 2007 *EHP Student Edition* at <http://www.ehponline.org/science-ed/> or download just the article "Chloramine Catch: Water Disinfectant Can Raise Lead Exposure" at <http://www.ehponline.org/docs/2007/115-2/ss.html#chlo>.
2. Review the Background Information, Instructions, and Student Instructions.
3. Make copies of the Student Instructions.

MATERIALS (per student):

- 1 copy of the May 2007 *EHP Student Edition* or 1 copy of "Chloramine Catch: Water Disinfectant Can Raise Lead Exposure," preferably in color
- 1 copy of the Student Instructions

VOCABULARY:

- blood lead level (BLL)
- carcinogen
- chloramines
- chlorine
- coagulation
- corrosive
- Environmental Protection Agency (EPA)
- fluoridation



BACKGROUND INFORMATION:

A study was completed in Wayne County, NC, that examined the blood lead level (BLL) in individuals, mostly children, segregated by their municipal water supplier: Wayne Water Systems (WWS) or Goldsboro Water Systems (GWS). According to the authors of the study, those receiving water from GWS, which uses chloramines for water supply disinfection, had higher mean BLLs. WWS uses chlorine, the more traditional water disinfectant, and its customers have lower BLLs.

The study attempted to address the numerous variables that impact BLLs and, through complex statistical analysis, accounted for variables like income and race, which supposedly shows the potential effect of chloramines on BLLs. The authors do admit to potential “artifacts” in the analysis that may confound the results and lessen the strength of interpreting those results. The authors state [Miranda et al. 2007]:

A two sample t-test assuming equal variances revealed that the mean BLL was significantly higher ($p < 0.00001$) for children residing in residential tax parcels whose water source relied on chloramines for disinfection (mean BLL = 4.93 $\mu\text{g/dL}$) compared with those whose water source did not rely on chloramines (mean BLL = 4.19 $\mu\text{g/dL}$). This may, of course, result solely from artifacts such as the GWS serving more of the older housing stock or the GWS serving more homes in less well-maintained areas.

In this lesson, the students are asked to identify and analyze some of the weaknesses in the study by evaluating a graph from the original research and using information provided by the authors themselves. Identifying weaknesses and other possible explanations for results is part of the scientific process. Scientists do this by being self-critical (i.e., pointing out their own weaknesses) and by peer-reviewing each other's work through publication.

Reference:

Miranda ML, Kim D, Hull AP, Paul CJ, Overstreet Galeano MA. 2007. Changes in blood lead levels associated with use of chloramines in water treatment systems. *Environ Health Perspect* 115:221–225; available: <http://www.ehponline.org/members/2006/9432/9432.html>

RESOURCES:

Environmental Health Perspectives, Environews by Topic page, <http://ehp.niehs.nih.gov/>. Choose Drinking Water Quality, Water Pollution

American Water Works Association (AWWA), <http://www.awwa.org/>

DrinkTap.org (a website for water information developed by the AWWA), <http://www.drinktap.org/consumerdnn/>

City of Palo Alto Utilities—Chloramine frequently asked questions (FAQ), <http://www.cpu.com/docs/factsheets/water/quality/chloramine.html>

U.S. Environmental Protection Agency, Drinking water issues, <http://www.epa.gov/region9/water/chloramine.html>

► Implementing the Lesson

INSTRUCTIONS:

1. Hand out the article and the Student Instructions.
2. Have students complete the Student Instructions, working either individually or in small groups.
3. Discuss answers with the students to ensure learning goals are met.

NOTES & HELPFUL HINTS:

1. If you want to provide an additional challenge for the students, have them read the entire *EHP* research article “Changes in Blood Lead Levels Associated with Use of Chloramines in Water Treatment Systems” (available at <http://www.ehponline.org/members/2006/9432/9432.html>) upon which the *EHP Student Edition* article is based. Students could identify additional factors or variables not addressed in this lesson.
2. This lesson could be extended with more depth about other concerns about chlorine and chloramines. Aside from lead in drinking water, these chemicals also have other risks and suspected effects that could be discussed. These include treatment of water for fish tank use, chloramines being inhaled (i.e., in the shower, where water is more aerosolized), and exposure to trihalomethanes, among others. Students could also investigate the potential differences for exposure to pathogens for disinfection using chlorines or chloramines.



► Aligning with Standards

SKILLS USED OR DEVELOPED:

- Communication (written—including summarization)
- Comprehension (reading)
- Critical thinking and response
- Graphreading

SPECIFIC CONTENT ADDRESSED:

- Water chemistry
- Water disinfection
- Public policy decision making
- Critical analysis of published scientific studies

NATIONAL SCIENCE EDUCATION STANDARDS MET:

Science Content Standards

Unifying Concepts and Processes Standard

- Evidence, models, and explanation
- Change, constancy, and measurement

Science as Inquiry Standard

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Physical Science Standard

- Chemical reactions

Science and Technology Standard

- Abilities of technical design
- Understanding about science and technology

Science in Personal and Social Perspectives Standard

- Personal and community health
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

► Assessing the Lesson

Step 2: a. What factor(s) put a child at risk of lead exposure from drinking water?

The type of plumbing, fixtures, and/or solder used, which often corresponds with the age of the house; the chemistry of the water.

b. Assuming the presence of lead pipes or lead in solder, what qualities of the water itself can cause more lead to be present in the water?

Softness, acidity, chemicals added to the water to decrease corrosivity or to coagulate solids, fluoridation.

Step 3: a. List two factors that made Wayne County, NC, a good area to study to seek an answer for how a switch to chloramines would affect blood lead levels (BLLs).

The main reasons are (quoting from the text):

- "The housing stock is distributed across a wide variety of age classes."
- "Wayne County screens a relatively large proportion of 1- and 2-year-old children for lead."
- "The children screened for lead are well-distributed across the housing age classes in the country."
- "Wayne County contains two main public water systems. . . . Wayne Water Systems [uses chlorine, whereas Goldsboro Water System] switched from using chlorine to using chloramines for disinfection in March 2000."



Step 4: a. Discuss the main idea of the graph.

Students should provide a clearly written, accurate answer that contains the following information. (It may be helpful to have students write several edited drafts of this graph summary. Writing and rewriting will help students better understand the graph and learn to communicate in a clear, concise manner.)

MAIN IDEA: Compared to Wayne Water Systems, the Goldsboro Water System is associated with higher mean BLLs for houses built before 1975. The mean BLL appears to increase around the time chloramines are introduced (Mar–Dec 2000) in the Goldsboro Water System but decreases in the years after (2001–2003).

- b. There are several data in this graph that do not appear to support the hypothesis that the introduction of chloramines to drinking water raises the mean BLL. Describe one.

Students may list any of the following reasons, or provide one not listed here. If a student provides a reason not listed here, be sure it is logical and aligns with the graphic information. You may want to take some class time to discuss and analyze these examples.

- Wayne Water Systems does not use chloramines to disinfect, but you see a similar spike in mean BLL for the Mar–Dec 2000 time frame. This may indicate another possible reason for the increase (e.g., more children were tested that year, or separating the data into two data points for the year 2000—as opposed to showing an average over the entire year—caused the jump).
 - The Goldsboro Water System shows a decrease in BLL over time. One could argue the chloramines actually decrease the lead exposure. (NOTE: We also do not know other potential extenuating factors. For example, if a community lead intervention happened in the Goldsboro Water System at the same time, that may have contributed to the BLL decrease. In addition, we do not know if the socioeconomic status of people in the Goldsboro Water System is lower compared to Wayne Water Systems users. This could account for the higher BLL—i.e., you have similar age housing stock, but one community maintains their homes better than the other, thus decreasing the lead exposure from more common pathways like lead paint.)
 - The graph does not include error bars or standard deviation. Thus, we cannot tell whether there is a significant difference between the mean BLLs for the Goldsboro Water System and Wayne Water Systems.
 - The jumps in the Wayne Water Systems data points (e.g., Mar–Dec 2000 and 2002 for housing built before 1926; Mar–Dec 2000 and 2003 for housing built 1926–1950 and 1951–1975) indicates there is variability year to year. The jump in Mar–Dec 2000 could be a result of natural variability in the data.
- c. Provide two possible reasons why housing built after 1975 has the lowest mean BLL over all of the time periods studied (refer to Step 2 and the article for information to assist with your answer).

The pipes may not have lead; the paint may not have lead (since leaded paint was banned after 1978).

Step 5: a. Pick one limitation from the current study and explain why that limitation may be important.

There are four main problems.

- More data are needed about other areas before extending these results to other municipalities. Simply, the results cannot be extended fully because they are site specific (for instance, other sites may have minor differences in water chemistry).
- Blood lead data are not randomly distributed in most places (Wayne County was desirable to study because it has a relatively high rate of screening). The limitation is that most other locales do not screen as high a percentage of children.
- There is suspected to be a time-based component to lead release in pipes—namely that chloramines dissolve a coating inside the pipes—and it is suggested that another chemically different coating will form over time. This component is not studied in this research.
- The researchers studied BLL, not the actual lead level in water coming out of fixtures in a home. Given that only 14–20% of childhood lead exposure is a result of drinking water quality, being careful to exclude other factors in a child's environment is important (and needs to be part of a study, not just extrapolated results).



► Authors and Reviewers

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Give us your feedback! Send comments about this lesson to ehpscienceed@niehs.nih.gov.



Chloramines and Elevated Blood Lead: Is the Effect Real?

Step 1: Read the article "Chloramine Catch: Water Disinfectant Can Raise Lead Exposure."

Step 2: Although most (around 80%) childhood lead exposure comes from deteriorating lead-based paint in buildings built before 1978, exposure to lead from drinking water may also occur. The study highlighted in the article focused on water as a potential route of exposure.

Read the following excerpt from the original research article and answer the questions that follow.

In 1991, the U.S. EPA (1991) set a maximum contaminant level goal for lead in drinking water of zero and an action level of 15 ppb [parts per billion]. Although water supplies themselves can be contaminated with lead, most lead in drinking water comes from residential plumbing (Davidson and Rabinowitz 1991). Lead piping was uncommon after the 1930s, but lead soldering was common and legal until 1986, and some plumbing fixtures today still contain lead (Maas and Patch 2004; Safe Drinking Water Act Amendments of 1986; Troesken and Beeson 2003). Lead is soluble in water, and this solubility is markedly increased by high water softness and acidity (Davidson and Rabinowitz 1991; Gaines 1913; Raab et al. 1993).

Chloramines alter water chemistry and often must be accompanied by other changes to water treatment (U.S. EPA 1999). Several recent studies provided evidence that the introduction of chloramines to water systems with lead-containing pipes, fixtures, or solder may increase the amount of dissolved lead in water because of changes in water chemistry; interactions with additives such as coagulants or fluoridation agents may remove lead dioxide scales originally formed during decades of chlorine-based disinfection (Edwards and Dudi 2004; Maas et al. 2005b; Schock 1990; Schock et al. 2001; Switzer et al. 2006). This leaching might be managed to some extent by the addition of anticorrosivity agents during the water treatment process; however, the details of all the related environmental chemistry are not fully understood and are highly dependent on the particular chemical interactions found in each water treatment and distribution system (Edwards and Dudi 2004; Edwards et al. 1999; Lin et al. 1997; Schock 1989).

- a. What factor(s) put a child at risk of lead exposure from drinking water?

- b. Assuming the presence of lead pipes or lead in solder, what qualities of the water itself can cause more lead to be present in the water?

Step 3: Refer to the excerpt below from the original research article and answer the question that follows.

Wayne County provides an ideal setting for [this research] for several reasons. First, the housing stock is distributed across a wide variety of age classes (Table 1), with approximately 15.6% built before 1926, 9.3% between 1926 and 1950, 35.5% between 1951 and 1975, and 39.6% after 1975. Second, Wayne County screens a relatively large proportion of 1- and 2-year-old children for lead, ranging from 75.5% in 2000 to 76.1% in 2003. As shown in Table 1, the children screened for lead are well-distributed across the housing age classes in the county. Third, Wayne County contains two main public water systems that together provide water for approximately three-fourths of the residential tax parcels within the county. Approximately 70% of residential tax parcels obtain drinking water through the Wayne Water Systems (WWS). These systems use chlorine for disinfection and sodium fluoride for fluoridation, and do not use an anticorrosive; these treatment options did not change over the course of the study period (1999–2003). Another 28% of residential tax parcels obtain drinking water through the Goldsboro Water System (GWS). This system uses fluorosilicic acid for fluoridation and zinc orthophosphate for anticorrosion. The GWS switched from using chlorine to using chloramines for disinfection in March 2000. This combination of sources of drinking water and treatment strategies allow us to compare outcomes within and across water systems.

Table 1. Distribution of year built for housing stock and for residences of screened children.

Year built (residential)	Residences of screened children (%)	Wayne County housing stock (%)
Pre-1926	16.5	15.6
1926–1950	7.7	9.3
1951–1975	36.0	35.5
After 1975	39.8	39.6

- List two factors that made Wayne County, NC, a good area to study to seek an answer for how a switch to chloramines would affect blood lead levels (BLLs).

Step 4: Figure 3 (below) shows data from the original research article. Review the graph and answer the questions. Remember, GWS refers to the Goldsboro Water Systems which uses chloramines for water supply disinfection, and WWS refers to Wayne Water Systems, which uses chlorine for disinfection.

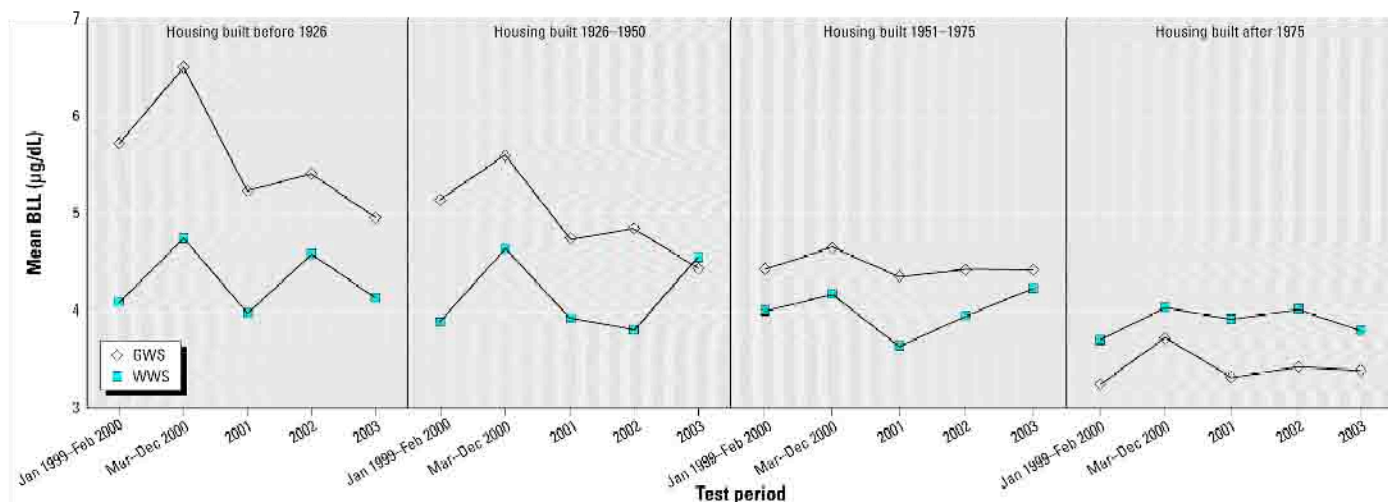


Figure 3. Mean BLLs by test period, by age of housing.



- ehponline.org/science-ed



Step 5: Read the excerpt from the original research study provided below, then answer the question.

Several caveats must be mentioned that temper the possible conclusions from this study. First, although the results are directly relevant to Wayne County, the extent to which they can be extrapolated to other areas in North Carolina, the Southeastern United States, or the United States more generally is yet to be determined. We are currently pursuing the data required to replicate the current study in other locations. Second, blood lead surveillance data are decidedly nonrandom in that programs typically target children living in the highest risk housing, based, in many cases, on age of housing. However, because Wayne County screens such a high proportion of young children, this concern is somewhat mitigated. In spite of targeted screening efforts, the distribution of age of housing where sampled children resided differs by < 2 percentage points from the distribution for the whole county. Third, some environmental chemists hypothesize that the dissolution of lead from pipes into water after switching to chloramines is a transient process, because a new coating may eventually develop on the inside of pipes, effectively creating a new barrier between the water and the lead source. This temporal dimension is unexplored in the current analysis. Fourth, we did not analyze lead in water directly and thus can only indirectly suggest that the increase in BLLs after the switch to chloramines was caused by an increase in lead in drinking water. We are currently working with the State of North Carolina to identify houses to sample for lead in water based on a geographic sampling design; we will analyze these data when they become available.

- a. Pick one limitation from the current study and explain why that limitation may be important.

